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THE DYNAMO.

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How It is Made and How to Use It.

A Complete Description of the Various Parts of the Machine,
and How to take care of it. With other valuable Electrical Information for the use of those having
charge of Electric Lighting Apparatus.

FULLY ILLUSTRATED WITH MANY NEW PLATES AND CUTS.

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FIFTY CENTS.

FRED. M. KIMBALL & CO.
Electrical and Mechanical Engineers and Constructors,
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PREFACE.

This little book has been written for the use of those who are practically engaged in making or operating electric lighting apparatus. Some time since the writer was requested by his own men to give them some elementary instruction in matters relating to the work on which they were employed. This request resulted in a series of twenty minute noon talks on the subject matter of this book. The desire having been expressed that a digest of some parts of these talks be printed, has now led to the publication of this pamphlet. It makes no pretence to teach those who call themselves electricians, and is not intended for their use. It further is not all that could be desired from a literary point of view. But, written as it has been, a little at a time, and under the pressure of the author's regular business, it is adapted and intended for the practical, everyday electrical mechanic. It is thought that the definitions and facts are, so far as possible, in popular language, correct and accurate, and if the book does as much good to those into whose hands it shall fall, as the "talks" from which it had birth did to those who listened, then its purpose will have been completely served and its author amply compensated.

The Author.

May 1, 1888.

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ELECTRICITY.

The question, "What is Electricity?" has often been asked, and although a great many attempts have been made to meet it, a satisfactory answer has never been given. In fact, at the present time we do not know. It is sufficient for our purpose, however, that we do know what the effects of electricity are, and that we are able to so arrange matters as to bring about many such effects at will. As these remarks pertain to the commercial aspect of the use of electricity, it is therefore of little consequence that we cannot answer the question in its first named form. The effects of Electricity and the causes that give rise thereto, are now so generally well known, that we can in many cases readily predict what action will follow when we bring certain physical agents, or processes, to bear on any electrically charged body. The manifestations of electrical energy are capable of being propagated from one point to another, if a suitable path between such points is provided. And this is one of the most important of all the attributes of electricity. Without such a factor, in our present state of knowledge we could in no manner avail ourselves of this most powerful and wonderful agent. Before going further with our subject matter, let us make a brief reference to one of the most important laws of Physical Science, **"The Conservation of Energy."**

Briefly and in part, this law states that no work can be done by any force or matter unless an equivalent amount of work has previously been done on it. For example: a pile when struck by the hammer of a pile driver, penetrates into the earth. Why is it? Because the hammer was brought violently into contact with the head of the pile. The hammer alone and unaided, however, would be totally unable to accomplish such a result. And it only does so when it has been raised by a force due to some external agent. That is, work was first expended on the hammer in raising it. And then it had, by reason of the attraction of gravitation and the work previously done on it, a certain power of doing work on the pile if let fall, and the amount of energy which was transmitted from the hammer to the pile, was not a particle more than that used in first raising the hammer preparatory to letting it fall. In fact the hammer did not deliver as much energy to the pile as had been expended on it, for part of the power of doing work which it possessed when at the top of the slide was lost in friction of the air and of the guides against the hammer during its downward course. But the total amount of energy expended in overcoming the resistance of the air, slides, etc., together with the work done by the blow on the head of the pile, was just equivalent to the energy required to raise the hammer to the dropping point in the first case. This law applies with the greatest force to all the phenomena of electrical action. It is impossible to produce any electrical effect without first doing work. No current can be produced from a dynamo or other source of electricity without the expenditure of energy in some form. Electricity then, as we will here consider it, is some agent which is readily available for use in doing work. **But no electrical effect can be produced except at the expense of some other form of energy.**

In almost all important applications of electrical phenomena, the object sought is to transmit from a certain point the results of work or energy to another point. This, as has already been noted, can be done in many cases by means of electricity, if we provide a suitable path between the two points. The progressive form of action due to electrical transmission of energy along such a path, is called technically the **current.** The word current when used in electrical language, must always be **associated with the idea of progressive motion in some form or other.** In just what manner this phenomena of progression in the path or conductor is accomplished, we are ignorant. But we are enabled very readily to so arrange or modify circumstances as to give rise to this action, whatever it may be. In case of the transmission of electrical energy, we speak of the path over or through which the action is propagated, as the conductor. In order to give rise to a current which is capable of doing work, we must first in some manner do work or expend energy on that which produces the current or that from which it proceeds. Suppose a long trough be placed on a level and containing water; the water has no power of running from one end to the other. It rests quietly and maintains a constant depth so long as no external force is applied to it. But raise one end of the trough and the water immediately rushes to the lower end, or what is the same thing, lower one end and the water will immediately flow to the end lowered. Now the water was put into motion because by the application of external force, a difference of level between the ends of the path, or trough, was brought about. It can thus be seen that energy in a moving, work-doing or dynamic form, can never be realized unless one part of the system through or over which it moves, is in some manner raised or lowered from the normal state or level of the system taken as a whole, when no energy or motion is present. This difference of level which gives rise to energy in any form, is called difference of **Potential,** and potential as ordinarily used means

the amount of change from the normal state which any point in any system possesses, or is made to possess in relation to any other point in the same system. Thus in an electrical circuit we speak of the potential between any two points along a wire or between the terminals of a lamp. The term potential as used here has simply a relative meaning, that is, it expresses the difference or condition of electrical level of one point in relation to another point. The unit of measure of difference of electrical potential is called a **Volt.** And when any two points in an electrical circuit are caused to differ in potential, there at once arises a tendency for these two points to again return to a normal state or equal potential. And this tendency is represented by a power called **Electro-motive Force.** The unit of measure of electro-motive force is also called a volt, i. e.: If two points vary in potential by a difference of ten volts, the tendency of a current of electricity to move from one to the other, would be such an amount as, if measured, would equal an electro-motive force represented by ten units or volts.

TECHNICAL TERMS.

Inasmuch as we shall use various technical terms in the following pages, it may be advisable to consider a few of them and their meaning before proceeding further:

Current (C) is that progressive form of electrical energy whereby electric effects are transmitted from one point to another. The unit of measure of rate of flow of an electrical current is called an **Ampere.**

Electro-Motive Force (E. M. F.) is that attribute of a current of electricity in virtue of which it is capable of passing from one point to another along a conductor, or doing work of any kind. The unit of measure of E. M. F. is called a **Volt.**

Conductor is a path through which electrical energy or effects may be transmitted from one point to another.

Conductivity represents the degree of ease which any path offers to the passage of an electrical current. Thus, silver, copper, iron and various other metals conduct electricity readily, therefore they are called good conductors.

Rubber, slate, glass, shellac, and various gums conduct electricity in a very indifferent manner, and are called poor conductors.

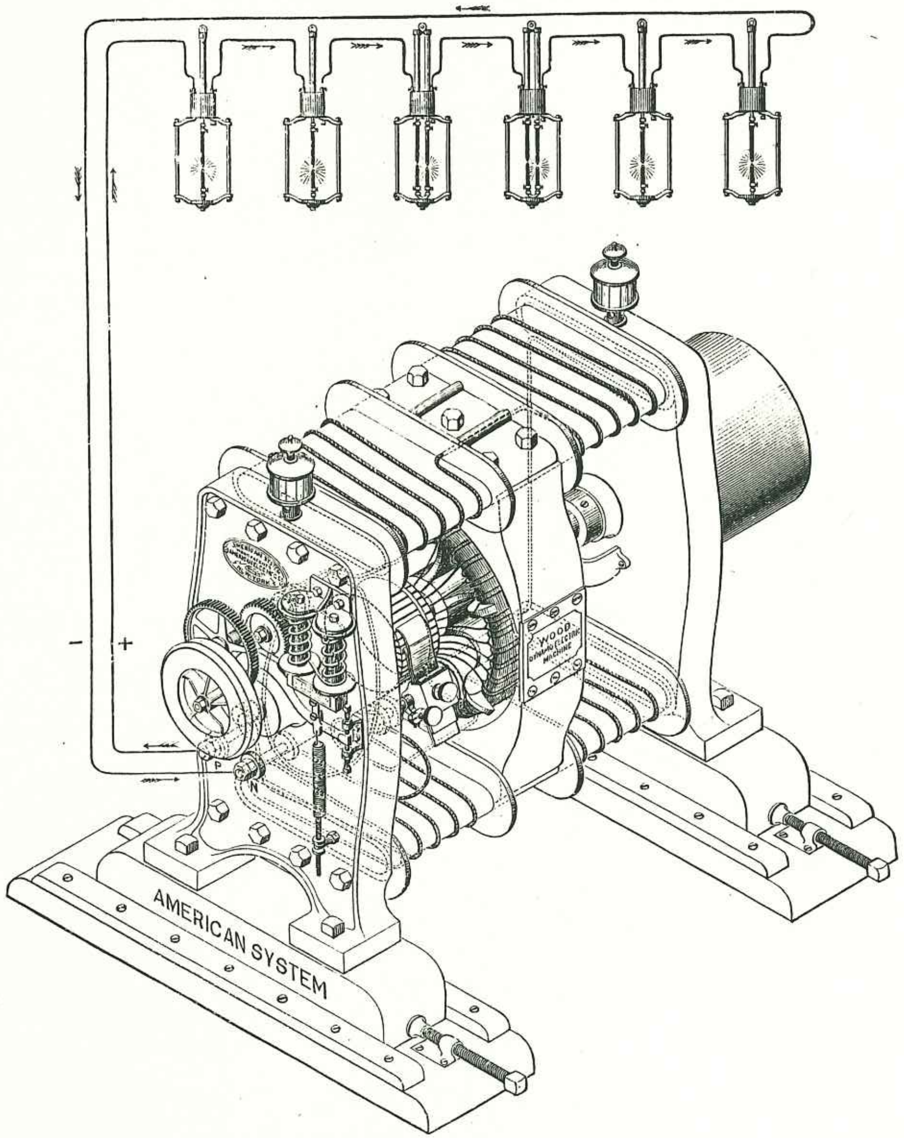
Insulator is the usual name for an exceedingly poor conductor of electricity.

Resistance (R) represents that state of a body which tends to prevent the passage of a current through it. All insulators offer great resistance to the passage of electricity through or over them. Resistance is a kind of friction, and the greater the resistance due to a body, the more work is required to force a current through it.

The unit of measure of resistance is the **"Ohm."** One hundred feet of No. 20 B. & S. copper wire has a resistance of about one ohm.

Circuit is that entire path through which a current travels or may travel. When there is any point in the circuit where an insulator is included over which only an infinitely small current can pass, the circuit is said to be **open.** For example, if we cut a wire apart over which a current is passing so that there is only air between its ends, we say the circuit has been opened, for only an infinitely small amount of electricity will then pass. When the circuit is completed in every part by good conductors, we say that it is **closed.**

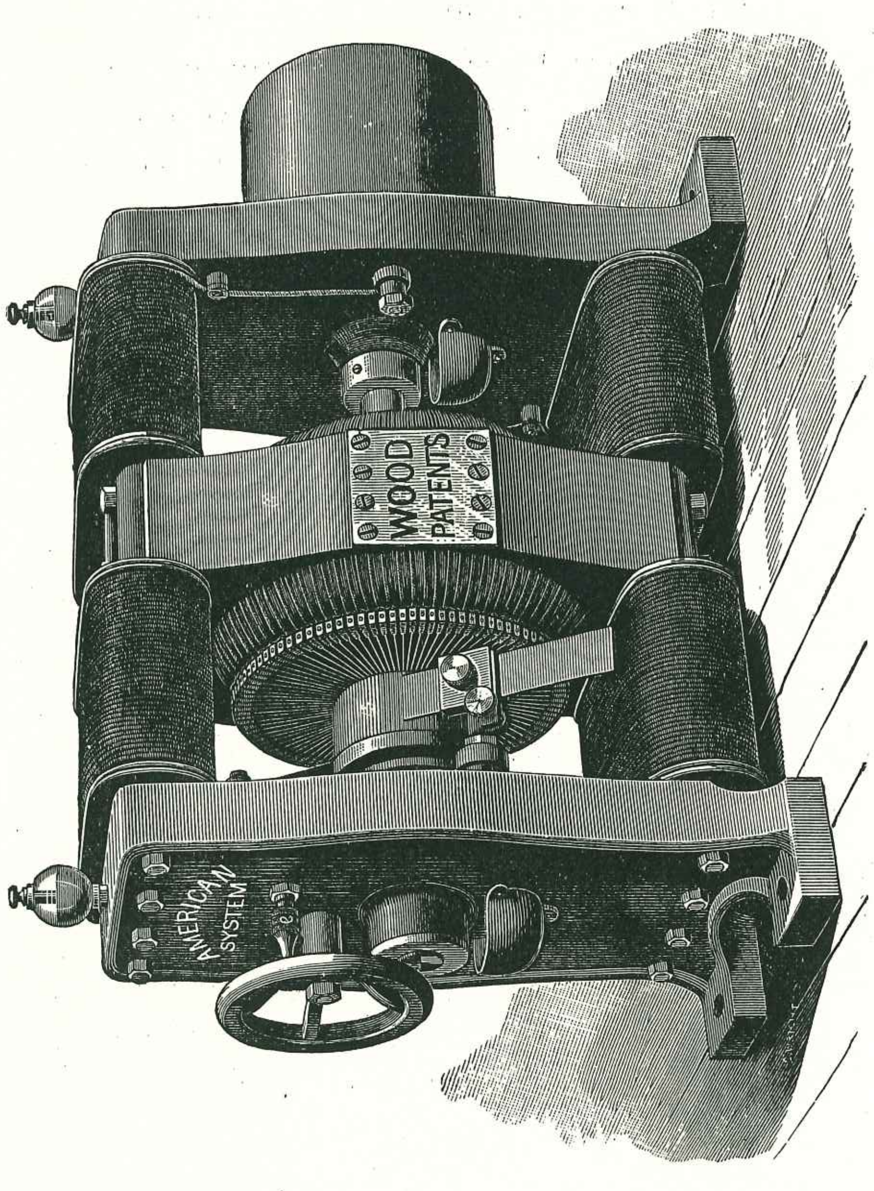
A circuit is said to have a **high resistance** when the material of which it is composed presents great obstruction to the passage of a current through it. In the case of a circuit in which all the apparatus is connected in **Series,**



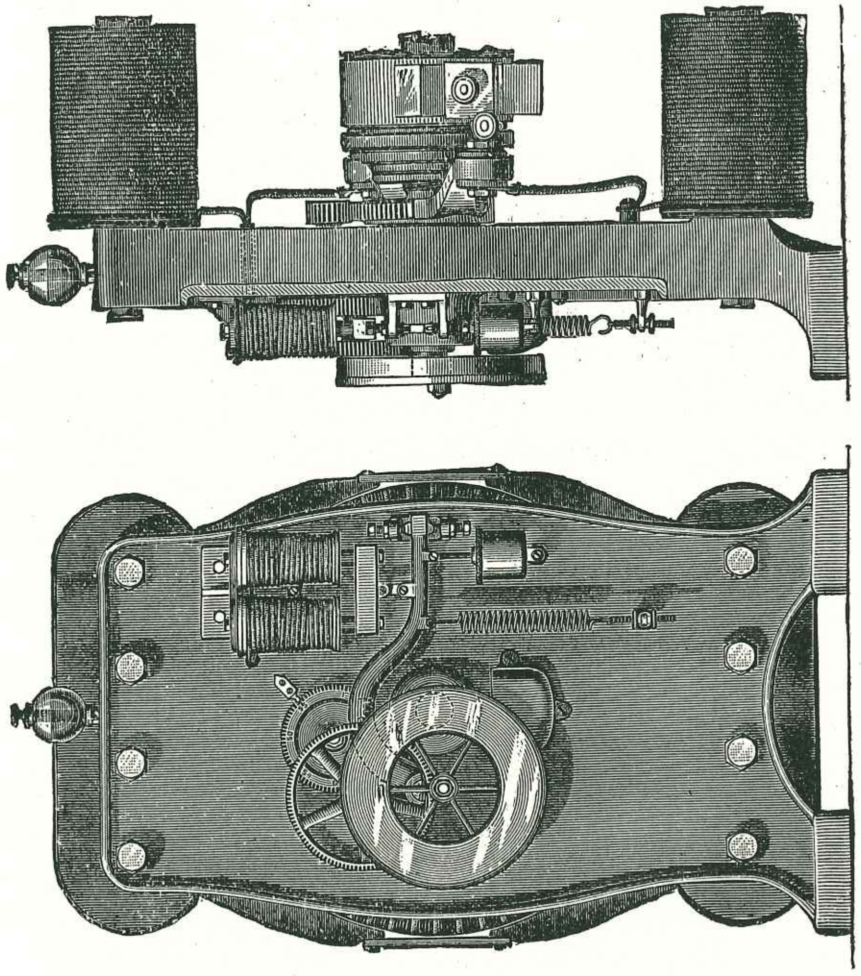
Arc Light Dynamo and Circuit of Lamps. Showing Manner of Connecting Apparatus in Series.

the resistance is comparatively high, for the current has only one avenue through which to pass, and it must therefore successively encounter the obstruction offered by each lamp, magnet, or other piece of apparatus through which it is sent. Thus, if there were five lamps in a circuit, each offering a resistance of four ohms, and it required a pressure of fifty volts to force the required amount of current through one lamp, then the lamps being connected in series or one after another, would offer a united resistance of five times four, or twenty ohms, and to force the given current through this twenty ohms would require an electro-motive force five times as strong as for one lamp, or 250 volts.

For Arc lights, which are generally operated in series, it will be seen that a dynamo is required which, while it gives a current of constant strength, can be so regulated as to deliver this current at an electro-motive force proportional to the resistance of the circuit, the resistance varying with the number of lamps in operation. Circuits over or through which the current can pass easily, or having the apparatus connected in **Multiple Arc,** are as a rule of **low resistance,** for the more paths by which the current can go from one point in a circuit to another, the lower will be the resistance of the circuit as a whole.



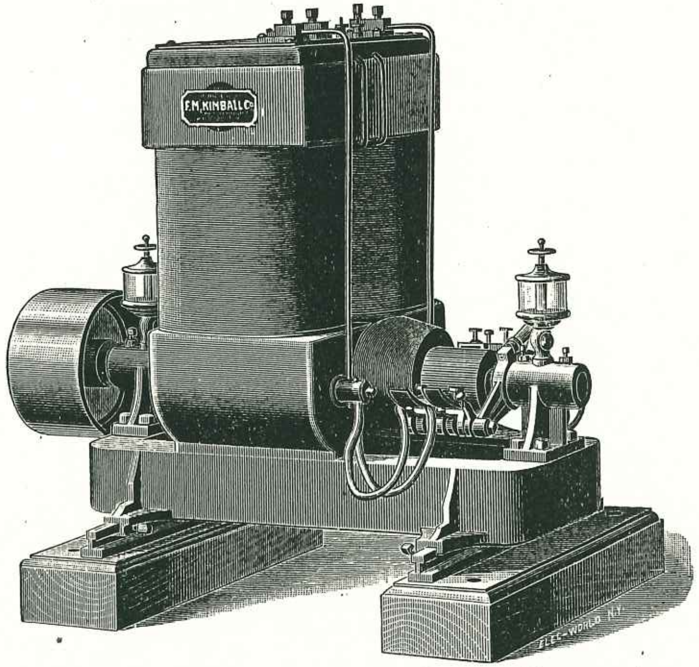
Arc Light Dynamo, for Operating Lamps in Series.



Cut Showing Regulator on Arc Light Dynamo.

If one path presents a resistance of forty ohms, then arranging another path parallel with the first and of the same resistance in itself, will make the total or joint resistance of the two paths only one-half that of one, or twenty ohms. If we provide four paths between the points, each alone having a resistance of forty ohms, then the joint or total resistance of the whole system of four wires will be reduced to one quarter that of one, or ten ohms. Thus every additional path offered to the passage of the current decreases the net resistance proportionally. Having a constant pressure or electro-motive force between any two points in a circuit, the more the resistance between such points is decreased, other things being equal, the more current can be made to flow through the circuit with a given **E. M. F.** In the case of incandescent lamps, they are usually connected in multiple arc, or parallel paths.

Suppose a certain lamp which has a resistance of eighty ohms, and requires an **E. M. F.** of eighty volts to force one ampere of current through it; then if five of these are connected in multiple arc, the net resistance of the system of five will be reduced to one-fifth that of one, or sixteen ohms. The net resistance being decreased to sixteen ohms, the **E. M. F.** of eighty volts will be able to force five times as much current over the circuit as in the first case or five amperes.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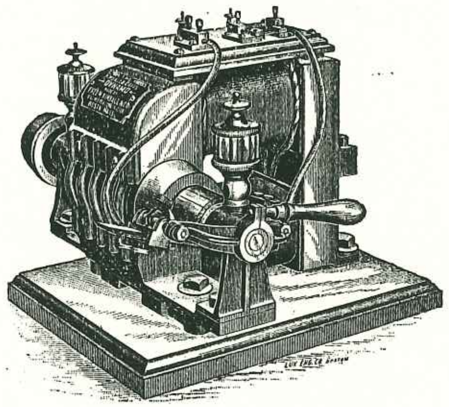
Dynamo for Operating Incandescent Lamps in Multiple Arc.

And as each lamp requires one ampere, the total amount of current going over the several paths will be just enough for the five lamps. From this it will be seen that for incandescent lighting, a dynamo is required that shall keep the current at a constant pressure, but will supply more and more current, as the resistance of the external circuit is lowered by the opening of other lamp paths.

In general, if there are a certain number of paths of the same resistance between two points, the current flowing through the circuit will be divided equally between them. If, however, one path has more resistance than the others, then less current will go by that way than by any of the others. Thus it is that on one circuit, incandescent lamps will be found of various degrees of brilliancy. This follows from the fact that the lamps vary in resistance, and the current is therefore not equally divided between them. Some having a low resistance will get a large current and will be very bright, and some having high resistance will get little current and be dull. In selecting incandescent lamps it is of the utmost importance to choose such as have a uniform resistance, if the best results are to be obtained.

A Short Circuit takes place when the current is diverted from its proper course, by some path having lower resistance being opened to it than that in which it is intended to go. When such a short cut is offered, the greater part of the current will be diverted away from its proper course and expend its energy in useless or dangerous heating of the conductor by which it was so diverted.

Induction so far as used in this book, is that peculiar operation by which electrical effects are caused to appear in a wire lying near another wire, which carries a varying current of electricity. Inductive effects can only take place in the secondary wire at such times as the current in the primary wire varies in strength. For example, at the moment of stopping or starting the current in the primary wire, a distinct but momentary current may be noticed in the secondary. The strength of this secondary current is proportional to the strength of the primary, and to the distance separating the two wires or systems of wires. It must be understood that there is no metallic connection or other conductor joining these two systems. The current in the secondary being produced simply in consequence of the presence of the other near it. It is not within our limits to discuss just how the phenomena occurs.



DYNAMOS.

A Dynamo is a machine for converting **Mechanical Energy** into **Electrical Energy.** It consists essentially of two or more **Magnets** mounted on a suitable base, and a so-called **Armature** or coil of wire, rotating between the **Poles** of such magnets. The armature is the seat of conversion of the mechanical energy supplied to the pulley, into the electrical energy manifested as current in the circuit. It is quite evident that all the mechanical energy supplied to the pulley cannot be converted into electricity, for a part will be lost in mechanical friction of the moving parts of the machine, the resistance of the air, etc. Good dynamos convert from 85 to 95 per cent. of the energy supplied into electricity. It is popularly supposed that there is great friction between the armature and the magnets. This is the very opposite of the fact, for there should be absolutely no friction of this sort on the armature. There is, however, a peculiar **Magnetic Friction** on the armature of a dynamo when in motion, which acts like an exceedingly powerful brake, and it is only by continually overcoming this friction that any current is generated in the armature coils. That is, the great work done in a dynamo is that required to pull the armature around against this magnetic

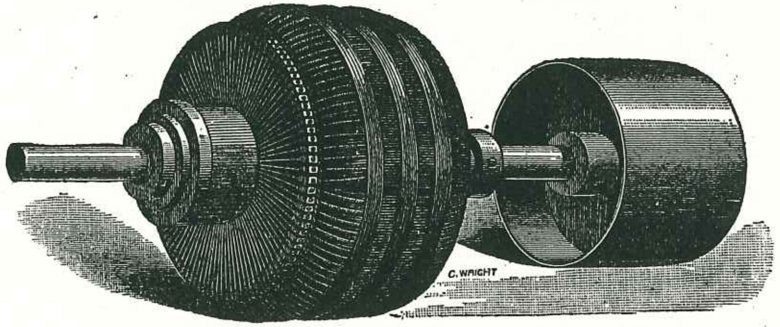
friction or tendency to rotate backwards. The mechanical energy or work exerted in this constant pull, is converted into what we call current. When the field magnets are excited, or caused to assume a magnetic state by the passage of a current of electricity through their coils, there is set up between their ends or **Poles,** a so-called **Field of Force.** This field of force makes itself manifest in the space between the ends of the magnets, by causing a piece of iron or steel, if introduced into this space, to be powerfully attracted toward one side or the other, according to the position of the iron or steel in regard to the magnets. In fact the term field of force, as employed by dynamo builders, means that space in which the invisible power, shown in the phenomena of attraction of iron or steel to a magnet, is most marked or concentrated. It has been found that if a properly wound coil of wire be rapidly rotated in this field of force, there will be set up in it a current of electricity which will last only so long as the motion continues. The exact explanation of why this occurs, would require more space and technical language than it is the province of this sketch to give. Further, other things being equal, it is found that the more turns of wire in a coil, and the more coils we have properly connected together, the more powerful will be the current. Of all these facts we take advantage in building an armature. We make it revolve in its bearings as easily as possible, and we make it present as smooth a surface as possible in order that we may reduce the mechanical friction to a minimum, and thus loose as little of the mechanical power supplied to the pulley as may be. We wind as much wire on the armature as we can, giving due regard to various other demands of construction. It is necessary to have some kind of frame work or **core** to wind the wire on, and iron is almost universally used for this purpose, as it has been found that this iron core or frame aids very materially in keeping the **field of force strong and concentrated.** It is customary to build up this core of many small pieces, each separated from the other by asbestos cloth, paper, or some other like substance, as it has been found that if the core is made of one piece it is very liable to become hot after running some time. This heating is detrimental to the efficient working of the machine and tends to destroy the insulation of the wires.

The **Terminals,** or ends of the coils on the armature, are brought out at one end and connected to the **Commutator,** a device which facilitates conducting the currents generated in the armature out into the external circuit or path through or by which the electricity is conveyed to the apparatus where it is desired to use it. In order to take the current from the commutator, which is revolving rapidly, recourse is had to contact springs or **Brushes** of

copper, which bear on diametrically opposite sides of it, and assist in conducting the current to the external circuit. As it has been found that wrought iron is more easily magnetized than cast iron, the cores of the field magnets are very generally made of this material, while the pole pieces and yokes are made of cast iron. This construction is adopted simply to save expense. A magnet made wholly of wrought iron would be better. For winding the coils of both field magnets and armatures copper wire is universally used, on account of the fact that it offers a very easy path through which electricity may move. Silver is the best conductor, but its high cost debars it from commercial use. Inasmuch as it is always the object in building a dynamo to make it convert the largest possible percentage of mechanical energy supplied into electrical energy, all the materials used in its construction are chosen of such character as to do their work with the least possible waste, having regard, of course, to excessive expense, and thus while copper wire costs many times more than iron wire, yet, other things being equal, it will perform its function of conducting the currents of electricity, where they may be wanted, with far greater economy than would the iron. As in every business, there are certain technical names applied to the various parts of a dynamo, and we shall now look at and try to explain these various parts one by one.

THE PARTS OF A DYNAMO.

Field Magnets are those large, iron pieces wound round with insulated copper wire, between the ends of which the armature rotates. The parts immediately facing the armature are called the **Pole Pieces.** The parts on which the wire is wound are called the **Cores,** and the parts by which they are fastened together, or to the frame of the machine as the case may be, are called the **Yokes** or **Back Straps.** Field magnets of wrought iron are the most efficient, but the high cost of producing such large masses of wrought iron in suitable shape has prevented their extensive use. In a well proportioned machine there should be but a very small amount of magnetism perceptible on the outside of the field magnet when the machine is in operation. If the magnets will powerfully attract iron or steel in proportion to the size of the machine, it is very evident that the dynamo is not as economical as it should be; for all this effect of attraction or magnetisation should be concentrated into or through the armature. The coils on the magnet should not become warmer than can pleasantly be borne by the hand. If the machine runs cool ordinarily, then heating up of the field coils is a sure sign of over-

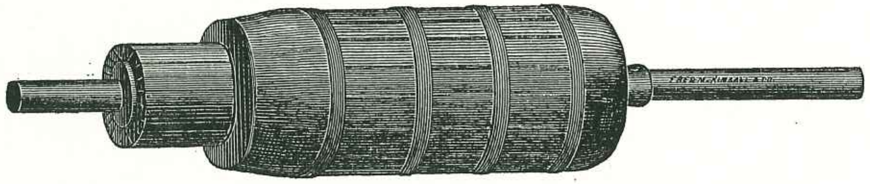


Gramme or Ring Armature, Showing Commutator.

loading the circuit, or some other trouble. The **Armature** is composed of a suitable core of iron mounted on a shaft and wound round, in a direction parallel to the shaft, with coils of insulated copper wire.

These coils are symetrically disposed over the entire surface of the core, and in the best dynamos the amount of wire and number of turns in each coil are the same. Armatures have from one to over one hundred coils according to their use and design. As a rule, the more coils into which a given amount of wire to be wound onto the core is divided the better the operation of the machine. The cores of the best designed armatures are made of a great number of soft iron disks strung on the shaft and insulated by paper, or some other thin, non-magnetic substance, from each other.

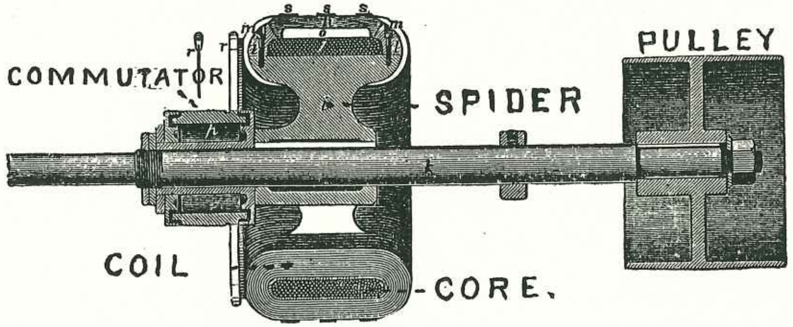
After such a core has been built up it is subjected to great pressure, in the direction of its length, in order to bring the disks solidly together, and finally held in position on the shaft by two heavy **Head Flanges**, one at either end; these head flanges are pinned or screwed to the shaft itself. In some armatures of the Gramme type and other ring armatures the core is made by winding up a ring composed of many turns of insulated iron wire. This ring is fastened into shape by insulating bands and mounted on the shaft by means of a so-called **Spider,** which is simply a hub and spokes of some non-magnetic metal. The insulated iron ring is then fastened over the ends of the spokes like the rim or felloe of a wheel. Armatures are of three general kinds—**Drum, Ring, and Multipolar.**



Drum Armature and Commutator.

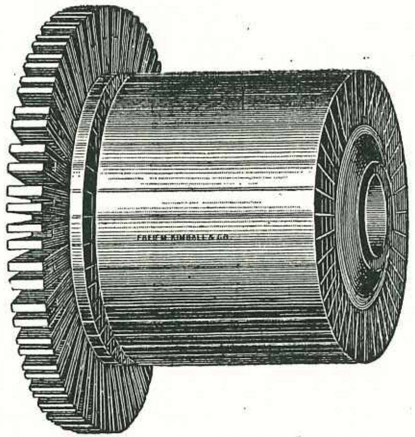
Drum armatures do not require a spider and their length generally much exceeds their diameter.

Ring armatures always require a spider or its equivalent, are generally larger in diameter than they are long, and have an air space between the ring and the hub. Both of these types present an approximately unbroken surface on the outside and little or no iron is visible. These armatures are mostly in use in direct current machines.



Section of Ring Armature Showing Spider, Core, Coils and Method of Insulating Segments of Commutator.

Multipolar Armatures consist of several soft iron cores, wound with insulated wire, mounted by one end on a hub somewhat resembling a cog wheel. They present a broken surface on the outside and considerable iron is exposed. These armatures are mostly in use in so-called alternating machines. The manufacture of an armature requires the utmost care as it is the very heart of a dynamo. The insulation of the separate wires and the various coils from each other demands the greatest attention, and further the whole system of wires must be very carefully insulated from the iron core and the frame of the machine. Again, owing to the high speed at which the armature revolves, it is very necessary to carefully and strongly confine the various wires and coils in their place by bands of hard brass or other non-magnetic wire, for, owing to the centrifugal force developed by the rapid rotation, every point in the armature has a strong tendency to fly out and off. As the wires are exposed to an enormous magnetic friction it is necessary to so confine them that they shall resist the tendency to slip around the core in a direction opposite to that of the armatures' rotation. This is effected in various ways, one general method being to drive hard wood pegs into the head flanges of the core between which pegs the coils are wound. If the number of feet of wire in every coil of an armature is not the same a tendency to spark at the commutator will be the result; and one of the most difficult problems of winding drum armatures is to thus make each coil exactly equal in length to the others. It is more easily accomplished in Ring or or Multipolar Armatures. The **Commutator** is composed of a number of copper strips, each thoroughly insulated from the other and all mounted on a so-called **Spool.** This spool is placed on the same shaft as the armature and the surface of the commutator is perfectly cylindrical. All the strips, technically called **Segments,** being not only insulated from each other, but also from the spool. The insulation of the commutator is of equal importance with that of the armature and a failure of this insulation will almost certainly produce trouble.


FRED. M. KIMBALL & CO.

COMMUTATOR FOR ARMATURE OF INCANDESCENT DYNAMO.

The commutator should have as many segments as there are coils in the armature generally speaking, and the ends of the coils are firmly screwed or soldered to the bosses on the segments made for that purpose. The order or method of connecting the coils to the segments differs in different dynamos, but the object to be obtained in all cases is to bring the currents generated in the various coils of the armature into the proper direction, to be taken off and into the circuit by the brushes. The **Brushes** are bundles of wires or strips of copper arranged so as to press on the commutator on diametrically opposite sides. They serve the purpose of collecting the current from the commutator strips, and supplying it to the main wires of the circuit It is often supposed that the friction of the brushes has something to do with the production of the current. This is not so. Only so much pressure should ever be kept on them, as to just keep good flexible contact between them and the revolving commutator.

PLATE I.

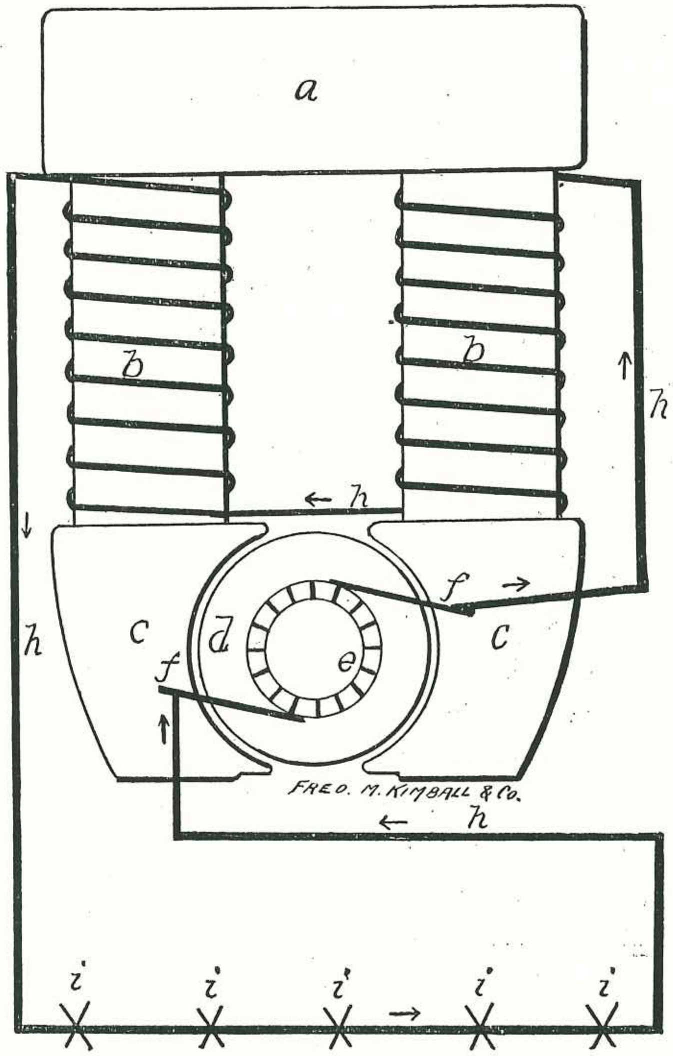


DIAGRAM OF SERIES WOUND DYNAMO.

a.	Yoke.	*e.*	Commutator.
bb.	Fields.	*ff.*	Brushes.
cc.	Pole Pieces.	*hh.*	Main or External Circuits.
d.	Armature.	*ii.*	Lamps.

KINDS OF DYNAMOS.

Dynamos are of various kinds. The simplest is figured on the opposite page. (**Plate I.**) In this form, known as the **Series Dynamo,** the whole current from the armature circulates through the field magnets of the machine and the circuit, only one path being offered. When the whole current thus passes through the various parts of the dynamo and the lamps, one after another, these parts are said to be connected in **Series** or **Tandem.** Arc light dynamos are, in general, connected in series. If the circuit be traced out in the figure, it will be seen that if we start at either brush and follow the conductors, only one course is presented for the electricity to travel over.

The same current which operates the lamps magnetises the fields. As there is a small amount of **permanent** or **residual magnetism** in the iron of the magnets of every dynamo, after they leave the factory, when the armature is rotated at the proper speed, and the circuit is closed, a very slight current is generated.

This, passing around the cores of the magnets, causes them to act with great magnetic force on the armature, and in a very short time sufficient current is developed to put

PLATE II.

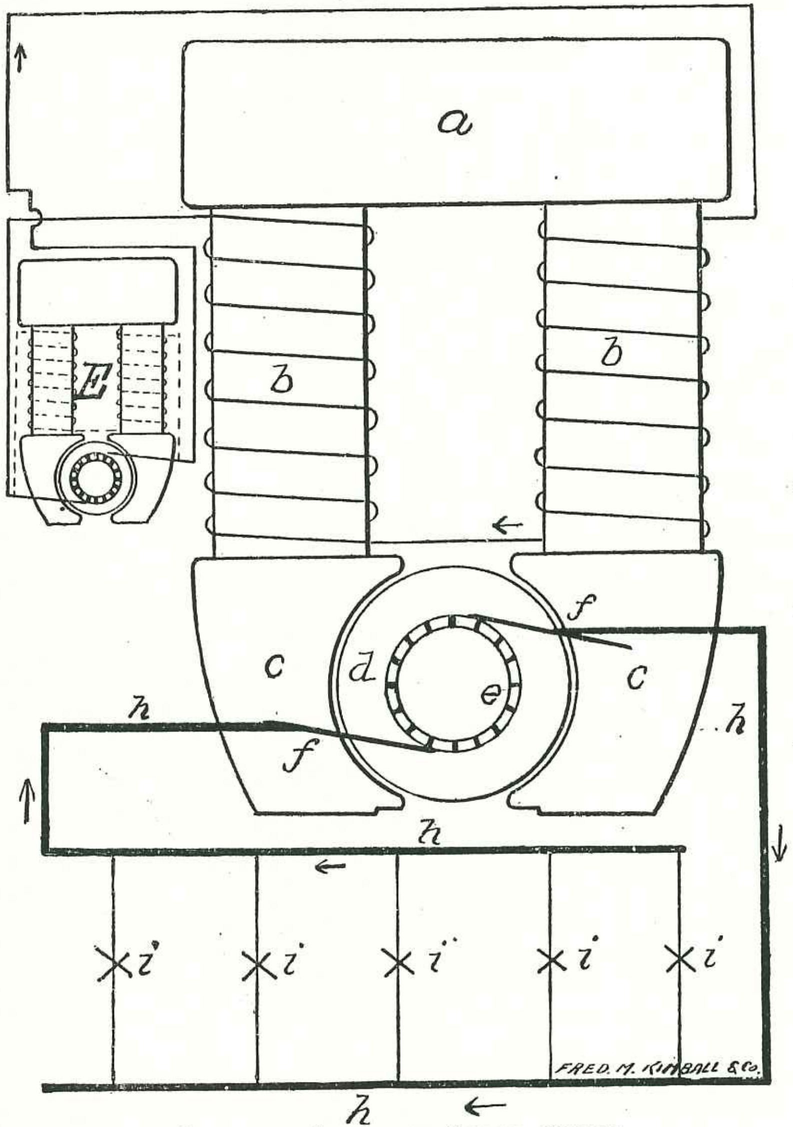


DIAGRAM OF SEPARATELY EXCITED DYNAMO.
a. Yoke. *bb*. Fields. *cc*. Pole Pieces. *d*. Armature. *e*. Commutator. *ff*. Brushes. *hh*. External Circuit. *ii*. Lights. *E*. Battery or dynamo used to excite the fields *bb*.

the lamps into operation. This process of strengthening the fields is called technically, **"Building Up."**

It will at once be seen that if a wire is broken in any part, electrical action will immediately cease throughout the circuit. The first Dynamos, known as **Separately Excited Dynamos,** (**Plate II.**) constructed, had their field magnets magnetized from some external source, as another dynamo, or a battery. The discovery that a dynamo could be so arranged as to excite its own field magnets, was one of the most important that has been made in Electrical Mechanics.

At the present time, only alternating current dynamos have their fields separately excited, and even in this class of apparatus, improvements are being and have been made, so that many alternaters excite their own fields.

The second class of dynamos which we will notice are known as **"Shunt Dynamos,"** (**Plate III.**)

The current generated in the armature is divided at X.X., one part passing around through the field magnets to energize them, and another and larger part going out into the external circuit, to operate lamps, etc.

This style of machine is used largely for operating incandescent lamps and motors, and also for charging storage batteries. In such a machine, starting from either brush, we find that at X the current divides, and thence has two

PLATE III.

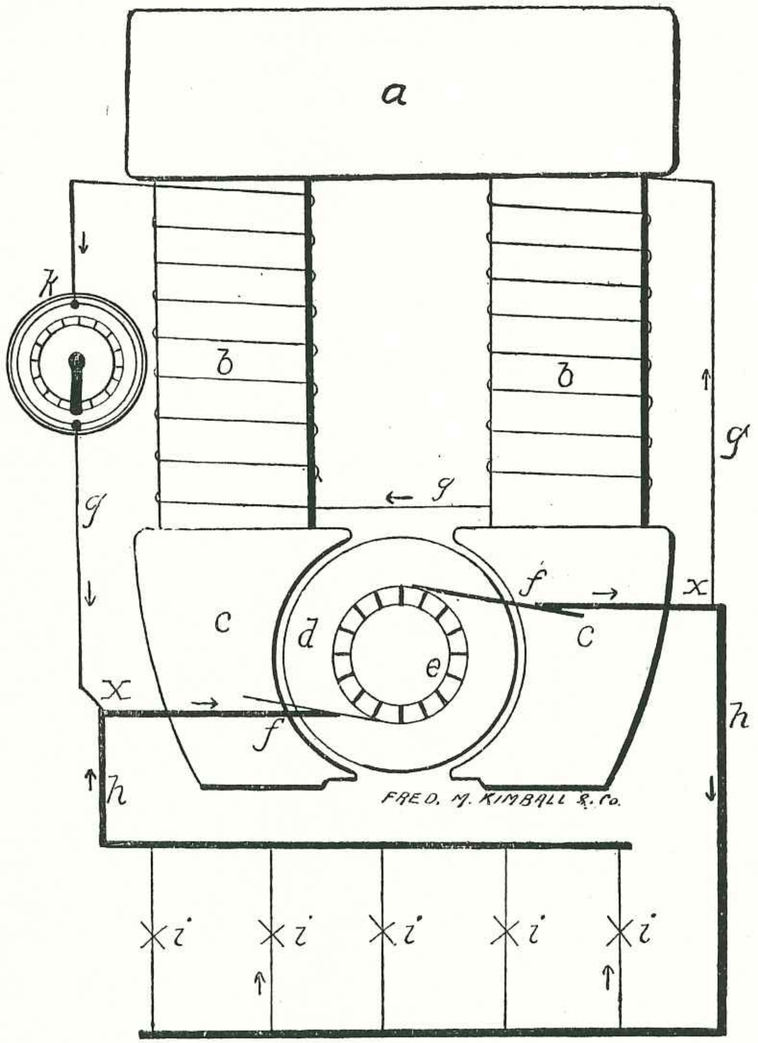


Diagram of Shunt Wound Dynamo.

a. Yoke. *cc.* Pole Pieces. *e.* Commutator. *gg.* Shunt circuit around the fields.
bb. Fields. *d.* Armature. *ff.* Brushes. *hh.* Main or External Circuit.
ii. Lights. *k.* Adjustable resistance in the circuit *gg.*
xx. Points where the field or shunt circuit connects with the main circuit.

paths, the path of high resistance, however, being that around the field magnets. In well designed dynamos this path should offer a resistance fifteen or twenty times as great as that through the lamps.

The path by way of the fields corresponds to a side track on a railroad, and when a part of the main current is sent off over this path, we borrow a railway expression and say it is **shunted.** Shunt machines are so named because the current needed to energize their field magnets, is shunted out of the main circuit. A **Resistance Box,** k, is generally included in the field circuit in order to control the amount of current passing around the magnets. If the main wire connected with such a machine be broken, all work in the external circuit will cease, but the fields will still hold their magnetism. But, if the shunt wire be broken the fields will be robbed of their magnetism, and all work in the entire circuit will cease.

Shunt wound dynamos are generally used for purposes which require a varying current and a constant **E. M. F.** For all general purposes the Shunt form is probably the most desirable.

With the rapid introduction of storage batteries a large demand for this class of dynamos has been brought about. They are less likely to become reversed in polarity, than Series or Compound wound machines, and are more

PLATE IV.

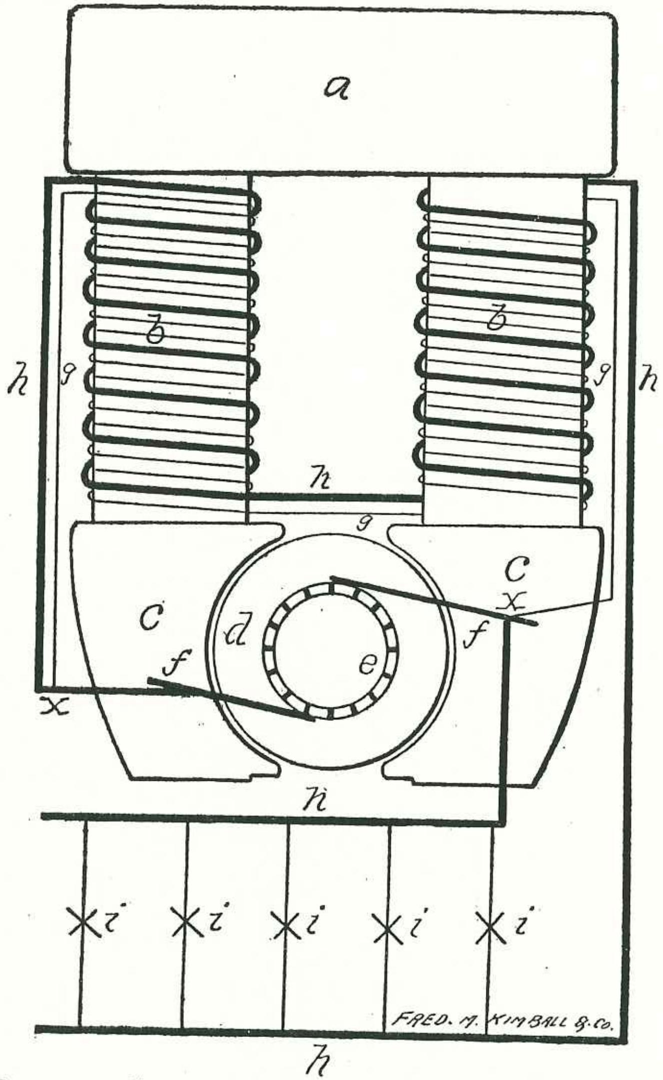


DIAGRAM OF COMPOUND WOUND OR SELF-REGULATING DYNAMO.

a. Yoke.
bb. Fields.
cc. Pole Pieces.
d. Armature.
e. Commutator.
ff. Brushes.
gg. Shunt Circuit.
hh. Main Circuit.
ii. Lamps.
xx. Points where the Shunt Circuit joins the Main Circuit.

economical than the latter in the matter of power required to operate them.

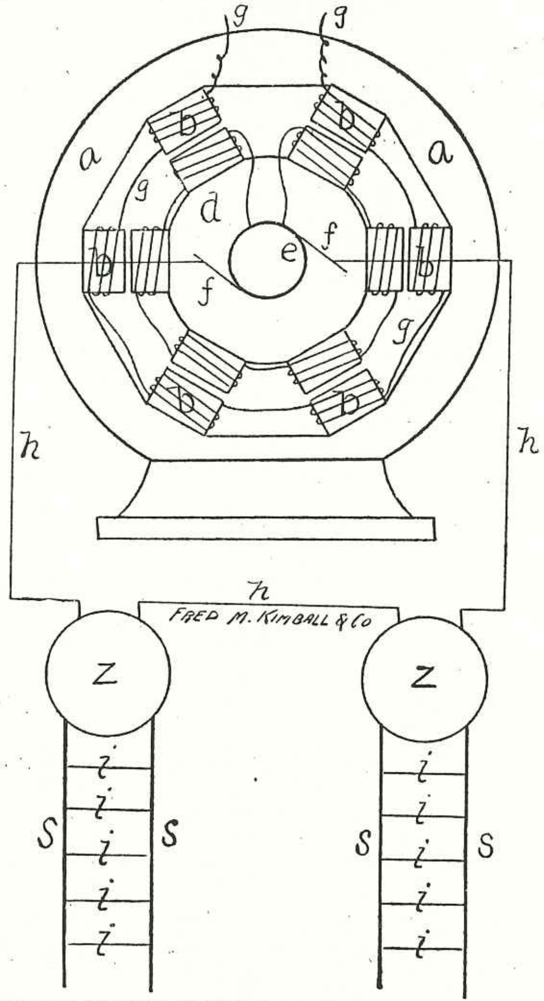
Compound Wound, or **Self Regulating** (**Plate IV.**) dynamos, combine a Series and Shunt winding, and are used in general for purposes requiring constant **E. M. F.,** and variable current. When the external circuit is open and the machine put in operation, current flows only through the fine wire or **Shunt coils** around the magnets.

The winding is so arranged that just enough current will circulate around these coils to cause the armature to develop the required **E. M. F.**

Now if the external circuit be closed, and the load be thus thrown on, a current will immediately circulate through the coarse wire, or **Series coils,** also, and increase the magnetism of the field.

As the output of the dynamo depends, within certain limits, on the strength of the fields, and as the strength of the fields depends upon the current circulating through their coils, it follows that if a demand for a heavy current is made in the external circuit, this same heavy current must pass also through the Series coils, and thus increase the output of the dynamo sufficiently to sustain the load. The construction of a Compound wound dynamo is a matter calling for very exact calculation, to so proportion the shunt and series coils that each shall do its proper

PLATE V.



SEPARATELY EXCITED DYNAMO FOR ALTERNATING CURRENTS.

aa. Yoke.
bb. Fields.
d. Armature with many poles.
ee. Contact rings.
ff. Brushes.
gg. Wires from Exciting battery or Dynamo to conduct current around the fields *bb.*
hh. External or main circuit.
ii. Lamps.
ss. Secondary or Lamp Circuit.
zz. Converters or Transformers.

---

amount of work. The armatures of all the dynamos thus far described, are so arranged by means of suitable commutators, as to deliver a continuous current in one direction to the circuit.

Another class of dynamos, called **Alternating Current** machines, are figured in **Plate V.** These machines have no commutators on the armature, for the main current, but its place is supplied by two so-called **"Contact Rings,"** and are so constructed as to send electrical impulses in opposite directions, alternately to the circuit, and they are generally used for operating incandescent lamps, at greater distances from the dynamo than would be practicable with direct current machines.

It is found most desirable to generate a current with these dynamos, small in quantity, but sent into the line under a great pressure or **E. M. F.**

The current is thus enabled to pass over very long lines of reasonably small wire. As it would not be desirable to introduce this powerful current into houses and stores, and further from the fact that by the small current used, only a few lamps could be operated in a group, recourse has been made to so-called **Converters.** These consist essentially of coils of wire suitably proportioned and placed very near each other in a proper case or box.

One of these coils is included in the primary circuit from the dynamo, and hence called the **Primary Coil,** and from the ends of the other, or **Secondary Coil,** wires lead to the lamp circuit. These coils have no direct electrical connection with each other. Several of these converters may be connected in series, in the primary or main external circuits.

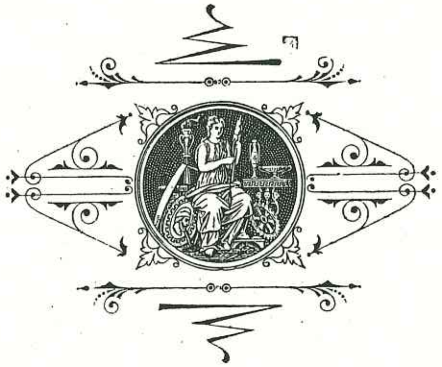
As the current from the dynamo passes through the primary coils of the various converters, first one way and then the other, in a series of impulses, another momentary current is set up in each neighboring secondary coil, by induction. These secondary currents are also alternating, but the converters are so constructed and proportioned that the secondary current has but a comparatively small and harmless **E. M. F.,** and correspondingly large current, these conditions being such as are most desirable for operating incandescent lamps in multiple arc.

The impulses are so frequent that the result appears as a constant electrical current in both circuits. The converters are usually placed on house tops or poles, where the danger from contact with the circuit carrying the powerful primary current, will be the least.

The principle advantages claimed for the alternating system, are, that the external circuit may be carried to a great distance, at a very small expense for wire as compared with a wire to do the same work in the direct system.

By properly proportioning the converters, secondary currents of any required strength or **E. M. F.,** within certain limits, may be obtained.

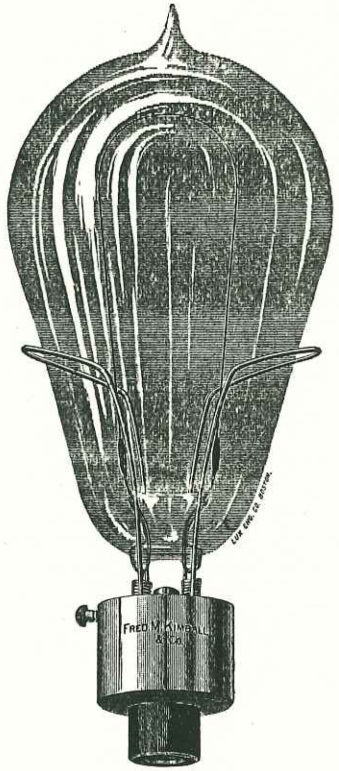
The above is an outline of only one of many methods of operating this system.



ELECTRIC LAMPS.

An **Incandescent, Electric Lamp** consists essentially of a **Filament** of carbon or other refractory substance enclosed in an air-tight glass globe from which the air has been thoroughly exhausted. The filament may be of various shapes and its size is proportioned to the current it is to carry and to the candle power it is intended to give. The carbon filament is supported within the glass bulb or globe by two terminal wires generally of platinum. These wires extend through the glass and afford, on the outside, opportunity for making electrical connection with the carbon filament within. Platinum wire is generally used for terminals, as it expands and contracts in nearly the same ratio that glass does. If it did not thus expand and contract the joint where the wire enters, the glass would soon be destroyed by unequal expansion and air would speedily enter the bulb and destroy the lamp. The reason that air is so carefully excluded from the bulb is that the white-hot filament would, in the presence of the oxygen in the air, be speedily consumed. At high temperatures many materials will be burnt up or disintegrated in the presence of oxygen which in its absence may be continued at great heat for a long time with little deterioration.

Further, the absence of air greatly decreases the amount of heat radiated from the filament to the walls of the bulb, and as may readily be seen, it is desirable to keep the lamp as cool as possible.

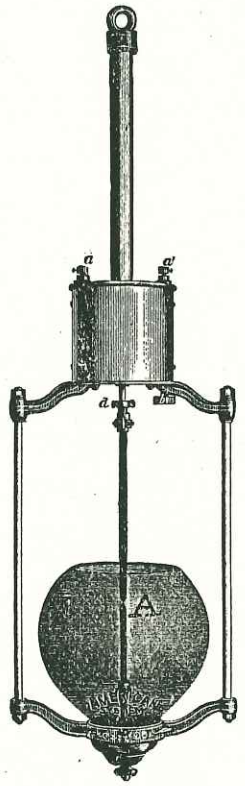

FRED M. KIMBALL & Co.

Incandescent Lamp and Holder.

The process of removing the air from the lamps is accomplished by the aid of powerful and specially devised air pumps. The large bulk of air is removed by mechanical pumps, and the final exhaustion is made by so-called mercury pumps, of which the two most generally in use are the Sprengel and Geissler, or their modifications, so named for their inventors. The carbon filaments are made from a great variety of material: silk, cotton, paper, bamboo, etc., etc. The substance is first wrought into the required form and heated in a suitable furnace until it is carbonized. Afterward the filament is attached to its conducting wires and mounted within the bulb. Finally, the air is exhausted, while the filament is maintained at a constantly increasing heat by the aid of a suitable current, in order that all air and gases held in its pores may be driven out. It is of great importance to remove all air and gas so far as possible, as their presence in the perfected lamp is very detrimental to long life. As the filament is so proportioned as to offer considerable resistance to the passage of the current, and as heat is always generated when electricity is forced through resistance, the tenuous carbon under the influence of the current becomes so hot as to give rise to incandescence. It is a familiar fact that when great friction is set up between two bodies they rapidly become hot and in case of the lamp the molecules of

the filament are probably impelled against each other so violently by the passage of the current as to create sufficient friction to cause them to become luminous.

An **Arc Lamp** is a piece of apparatus for producing light by means of the **Voltaic Arc.** In its simplest form it consists of an arrangement for holding two pencils of carbon in a vertical line, one above the other, and at a certain



Arc Lamp. The Arc is Formed Between the Carbons at *A*.
aa. Binding posts. *dd*. Carbon holders. *b*. Switch.

small distance from each other. The lower carbon is usually fixed and the upper one movable in the direction of its axis or length. The parts of the frame of the lamp which hold the lower and upper carbons, respectively, are insulated from each other. The rod to which the upper carbon is attached by means of a carbon holder or clamp is free to move up and down in the direction of the length of the carbon and this movement is so controlled by means of electro magnets that when the current is circulating through the lamp, the points of the carbons are kept at a small and constant distance from each other.

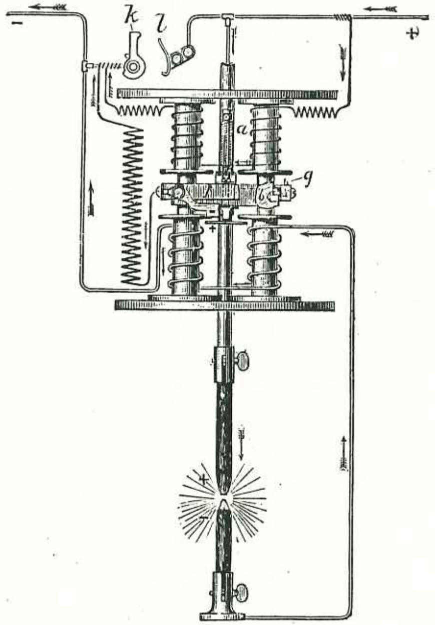


Diagram of Arc Lamp.
Showing lifting and shunt coils and path of the current through the lamp.

In the body of the lamp are located two sets of magnets. One called the **Lifting** set and the other the **Feeding** or **Shunt** set. The lifting set are in series with all the other apparatus in the circuit and the feeding set are connected as a shunt from the upper to the lower carbon of the lamp. The lifting set are so arranged that by means of suitable mechanism when they are energized by the passage of the current, they serve to raise the carbon rod and with it the upper carbon so that a small space intervenes between the two **Electrodes** of the lamp, as the carbons are called. If these are in their respective places and touching each other at their ends, as they will do when the current is cut out from the lamp, for the reason that the carbon rod, not being acted on by any force save gravity,

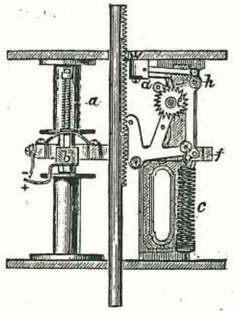


Diagram of Arc Lamp, Showing Feeding Mechanism.

will of its own weight slip down through its clutch and bushings, and electricity be then supplied to the lamp. Two things will immediately occur. The lifting magnet will at once raise the upper carbon by means of the rod and clutch so that it no longer touches the lower, and at the same instant the so-called **Arc** will be formed between the two carbons thus separated.

The contact between the carbons when in a state of rest is very poor and at the moment when the current is sent through this poor contact, which possesses a considerable resistance, great heat is developed. This heat vaporizes a part of the carbons and as they are just at that instant separated, the current continues to pass the break by means of the carbon vapor which is a partial conductor and with which the space immediately around the point of contact was filled. As the current continues to pass, vaporizing fresh portions of carbon, it tears off small particles of solid matter from the upper carbon, which, while heated to incandescence, are projecting against the lower. Particles also pass in the opposite direction, adding to the luminous effect.

Meantime this violent action at the terminals of the electrodes, has brought them up to a state of incandescence, the upper being hotter than the lower. All these things; the incandescent vapor or arc, the hot particles, and ends of the carbons, combine to give an exceedingly brilliant light. Gradually the distance between the electrodes become greater and greater, as the carbon is consumed, until at length the arc would be broken, were it not for the feeding magnets, which, when the arc has reached a predetermined length, cause the rod to "**feed**" or descend a little, thus lessening the space over which the arc passes. This burning away and feeding continue so long as the lamp remains alight.

In practice there are many more mechanical details than have been enumerated, but those spoken of are the principle ones.

From their great power arc lights are especially adapted for out of door illumination, or the interiors of large halls or assembly rooms.

Nearly all the prominent makes of Arc Light Machines are provided with automatic regulators, to constantly adapt the supply of electricity to the number of lamps in use on the circuit which they operate. The cuts, on pages 12 and 13, represent one of the prominent types of Dynamo and Regulator.

THE RELATION BETWEEN CURRENT, RESISTANCE, AND ELECTRO MOTIVE FORCE.

There are certain relations between the resistance of a circuit, the current flowing through it, and the electro motive force which drives the current through the circuit. These relations have been investigated by an eminent electrical scientist, and are expressed in a few simple rules known as **Ohm's Law.**

First: if we know the resistance of a circuit and the electro motive force under which the electricity is flowing, we can find the value of the current in amperes by dividing the number expressing the electro motive force in volts, by the number expressing the resistance in ohms. For example: the resistance between two points of a certain circuit is twenty ohms. The electro motive force between the same points as found by a volt meter, is eighty volts, then

$$20\overline{)80}$$

4 Amperes.

Second: If we know the resistance of any wire or part of a circuit, and wish to know what electro motive force is required to drive a current of a certain strength through this wire, it may be found by multiplying the number expressing the strength of the current in amperes by the number expressing the resistance of the wire in ohms. The answer will be the number of volts. For example: what electro motive force is required to force a current of four amperes through a resistance of twenty ohms;

$$\begin{array}{r} 20 \\ \underline{4} \end{array}$$

80 Volts.

Third: When it is difficult to measure the resistance of a part of a conductor between two points, we can find the resistance by dividing the number expressing the electro motive force in volts, by the number expressing the strength of current in amperes. For example: The electro motive force between two points is eighty volts. The current passing is four amperes. Then

$$4\overline{)80}$$

20 Ohms.

All these relations may be easily remembered by the well known formula

$$C = \frac{E}{R}$$

where **C** represents the number of amperes, **E** the number of volts, and **R** the number of ohms.

In all these formulæ, the number above the line is to be divided by the number below the line. When it is desired to know the value of the current in amperes, the formula is as above,

$$C = \frac{E}{R} \qquad (1).$$

When the value of electro motive force in volts is wanted, the formula becomes

$$E = C \times R \qquad (2).$$

And when the resistance is required we have

$$R = \frac{E}{C} \qquad (3).$$

These formulæ are of great value and should be studied carefully, because, by understanding them many practical questions can be quickly solved, as for instance: There is a certain group of incandescent lamps arranged in multiple arc, and it is desired to know what the resistance of the group is when hot. An ammeter, when placed in the circuit, shows a reading of ten amperes, and the volt meter, when one terminal is connected with the wire leading to the group, and the other terminal connected to the wire leading from the group, shows a reading of seventy volts. Now referring to the formula (3) for finding resistance, we have

$$R = \frac{E}{C}$$

Remembering that **R** is what we wish to find, and **E**

PLATE VI.

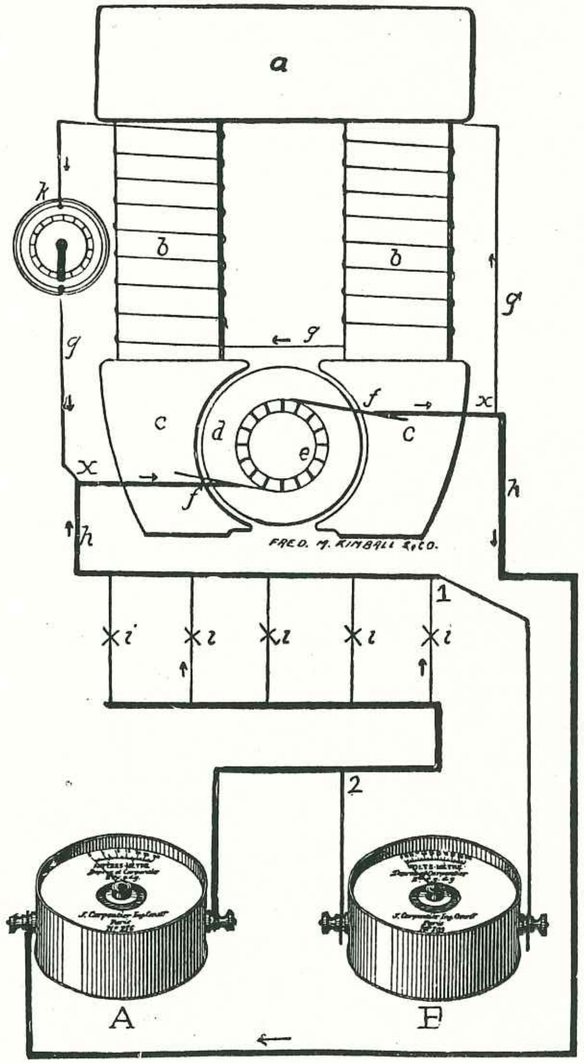


Diagram Showing Method of Connecting Volt and Ammeters in the Circuit.

A. Ammeter in Series. *B.* Volt Meter Connected in Shunt.

and **C** what we know, we write the formula thus,

$$R = \frac{70}{10} = 7$$

That is, the resistance of the group hot is seven ohms, or, if we wish to know the resistance of one lamp hot, and there were ten lamps in the group, then as the united, or net resistance of the ten lamps in multiple arc would be one-tenth that of one, the resistance of one lamp hot in this case would be 10 × 7, or seventy ohms. And the resistance of the lamp cold would be about twice that when hot, or 140 ohms. Here the formula allows us to find an important fact without the aid of other than the instruments to be found in every well regulated electric light station. To find the same thing by direct measurements, would involve the use of costly instruments, not readily attainable. Once more: If a person has twenty-five arc lamps, requiring an eight ampere current, hung as usual in series, and the maker has given their resistance when burning as four ohms each; and supposing further that the circuit in which they are hung is built of No. 6 B and S wire, and is two miles long. Then, neglecting the resistance of the dynamo, by referring to a table of resistance of wires, we find that two miles of No. 6 wire has a resistance of about four ohms, if the joints are all as they should be Therefore, twenty-five lamps, each

four ohms, would be 100 ohms, this, plus the resistance of the circuit, would be one hundred and four ohms. Now again referring to our formula for finding **E. M. F.**, (2), where we know **C** and **R**:

$$E = C \times R$$
$$E = 8 \times 104 = 832.$$

That is, the electro motive force at the terminals of the dynamo, would be approximately 832 volts. Special and costly volt meters or other instruments would be required to find this by the direct method of measurement.

Resistance and safe current of wires:

No. B. and S.	Resistance 1000 ft.	Safe Current.
	Ohms.	Amperes.
1	.12	127
2	.15	101
3	.19	80
4	.24	63
5	.30	50
6	.39	40
7	.49	32
8	.61	25
9	.77	20
10	.98	15
12	1.5	10
14	2.5	6
16	4.	4
18	6.3	3
20	10.	2

These formulæ are also useful when laying wire for incandescent lamps, etc.

To find what size wire is necessary to use in order to have no more than a certain loss in electro motive force in going from the dynamo to the lamps, suppose we wish to operate six fifty volt lamps, one hundred feet from the dynamo. Allowing one ampere for a lamp, the group of six would require six amperes. Now, if we have decided to run the dynamo at 52½ volts, so as to allow 5% drop, or loss of potential in the circuit, we can afford to lose only two and five-tenths volts in forcing this current of six amperes over one hundred feet of circuit, for we want to get fifty volts at the lamps, to enable them to burn at candle power. Then the question puts itself into this form, How small a resistance must a line two hundred feet long have, (100 out and 100 back,) when the current to be sent is six amperes, and we can only use two and one-half volts to do the work of forcing the current to the point where used?

$$R = \frac{E}{C} \qquad R = \frac{2.5}{6} = .416$$

.416 ohms for two hundred feet, or for one hundred, .2 + ohms. Looking in the table, we find that a wire having a resistance of two-tenths of one ohm per hundred feet, (two ohms per thousand feet) will be (nearest) No. 12 B and S, which will be the best size to use in this case.

As forcing a current over a line means overcoming resistance, and as a certain amount of electro motive force is used up in this way, it becomes of the greatest consequence to so proportion the wires as to get as small a drop as is consistent with conductors of reasonable price.

A little careful study of the above facts will lead to knowledge which may be applied advantageously in many ways.

GENERAL DIRECTIONS

For Setting Up, Starting, and Operating Electric Lighting Apparatus. — Dynamos are usually bolted to the bottom of the cases in which they are shipped. First remove the cover; then break away the sides and ends of the case, and the dynamos will be free from the packing box.

The machine should be located in a cool, dry place, where it will be free from dust, chips and sweepings.

The power to be used for driving may be supplied by steam, water, or gas engines, or any other source which will impart a steady motion to the shaft.

If the Dynamo is so large that it is shipped in pieces, care should be taken that the iron parts are perfectly clean and free from oil and grit where they make magnetic connections. That is, the joints between the fields and yoke, fields and pole pieces, etc.

Place the machine in line with the driving pulley; use an old and soft belt; a cotton one faced with leather is one of the best; the old belt will be more flexible and hug the pulley better than a new one. See that all the thumb screws are tight, all nuts and set screws turned up, and the connections properly made.

When the terminals of the circuit are connected to the main binding posts of the dynamo, the lamps are hung in position and all is ready, ship the belt on and start the machine. The oiling arrangements should be attended to as in any other piece of machinery. After the dynamo is fairly started and the oil cups have been set so as to deliver a constant, but small supply of oil, proceed to put in the brushes as follows: Having the main switch open, put the lower brush into the saddle, setting it forward until it bears on the commutator over its (the brush's) whole face or end. Then firmly clamp with the proper thumb screw. Next, by the small dog and spring, cause the brush to exert a gentle pressure on the commutator. Now proceed to place the top brush in the same manner, passing it so far through the saddle that it shall rest on the commutator, just diametrically opposite to the lower brush. Adjust the tension on this as before. The brushes will now, if everything is right, soon begin to show small sparks, more or less, according to the position of the brush yoke and the consequent position of the brushes. The screw handle, which holds the brush yoke in place, should now be turned, and the yoke, brush saddles, brushes and all, rocked up or down as the circumstances require, until no spark appears, or at least only a few blue bead-like sparks. Then lock the yoke by tightening the screw handle. Everything is now ready to light the lamps. To do this close the main switch, and the lamps will very soon give light. The brushes may, now that the load is on, require some slight adjustment, either individually, by means of the screws which bind them, or both at once, by means of the rocking yoke. In case of machines with automatic regulators, all the adjustment should be made with the brushes individually in their respective holders. There is no danger to be feared from manipulating the brushes of an incandescent machine, when the current is on, and little from the arc machine, if care be taken to touch only one brush at a time and nothing else. When all of the above adjustments have been made, the dynamo will require no further attention for some hours.

The brushes should be fed forward from time to time as they wear away, and the saddles should be shifted latterally from end to end of the saddle bar occasionally, so that the brushes may not wear a groove in the commutator, but wear it evenly over the whole surface. If they become rough or ragged they should be filled up at a bevel 45°, or trimmed squarely, if only one leaf thick, and their ends should be always kept bright and smooth. They should never be allowed to wear at a greater bevel than this. No more tension should ever be kept on than is necessary to secure a good, firm, but flexible contact. If the brushes

make sparks do not put on more pressure, but look to it that the commutator is smoothed up. Blue bead-like sparks are an indication of good working, although the best possible adjustment is indicated by the entire absence of sparks. Spitting and snapping red or green sparks in an incandescent dynamo, are a sure sign of (1) a rough commutator, (2) poor position of the brushes, (3) a short circuit on some part of the line or in the dynamo.

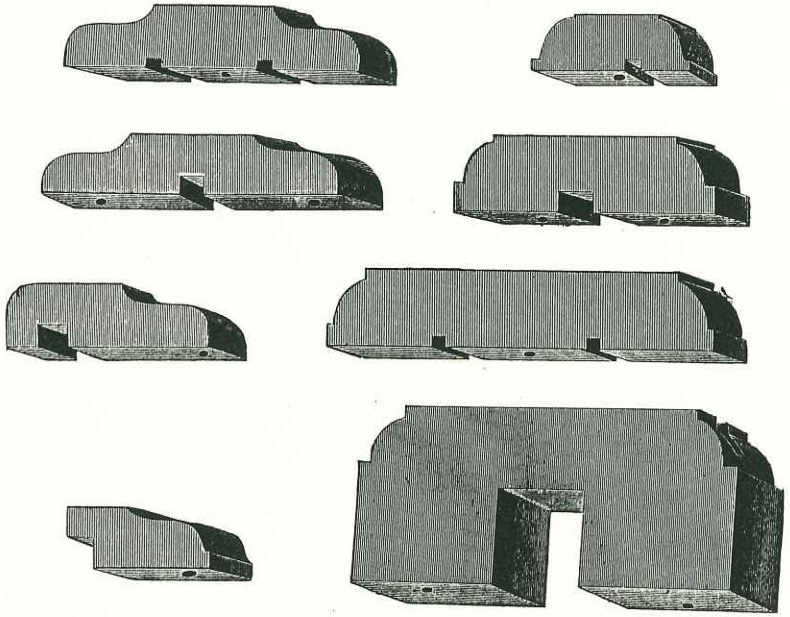
The commutator must be kept true and clean, otherwise the dynamo will not work well. It should be smoothed often by polishing with very fine sand paper held over a small flat block, and afterward thoroughly wiped with a piece of fine canvas or coarse duck. Never file the commutator, for this will almost invariably lead to trouble by pulling little strings over from one section of the commutator to another, and thus short circuiting it. Each copper strip is insulated from its neighbor by some non-conducting material, and when this insulation is destroyed or bridged over, trouble will occur. If the commutator gets very rough, take out the armature, mount it in a lathe on the centres of the armature shaft, and take as many light chips over the commutator as are necessary to take out the irregularities. This must be done with a sharp V shaped tool, and the lathe run at quick speed. Polish with sand paper and return to the machine. It sometimes happens that in turning up, if a very sharp V tool is not used, the metal of one segment is pulled across from one to the other in a "string." This brings the two segments into metallic contact, and while the strings remain the machine will not start up. Therefore, after turning up, always look the commutator over very carefully and remove any such strings as may have been formed, with a sharp knife or scraper. Each segment must be perfectly insulated from its neighbor, and no metallic "bridge" must exist.

The commutator, brush yoke, etc., must be kept very clean and free from copper dust and oil, especially must no oil ever be put on any of these parts. A very little vasoline may sometimes be used on a commutator to advantage. When turning the commutator use great care that the slide rest of the lathe does not abraid or tear the wires of the armature. "Eternal cleanliness is the price of a good running machine."

The circuit consists of necessary wires for leading the current to the lamps and their appendages. It is almost unnecessary to say that the circuit should be entirely metallic, and no grounds ever be put on or allowed to exist. It is advisable to test the insulation of the circuit every day, by means of a magneto or galvanometer. This may be easily accomplished by attaching one terminal of the magneto to a water, or gas pipe, and then while the

magneto is in operation, with the other terminal, touching any exposed portion of the metallic circuit, either at the switch board or on the dynamo. This test should only be made when the dynamo is at rest, and in sufficient time before starting the lamps to allow the making of any repairs found necessary.

All the windings on the dynamo and those in general on the lamps, are intended to be perfectly insulated from the frame of the machine or lamp. All wires of the circuit also are intended to be insulated from gas, water, and steam pipes, the earth, and the supports on which they are placed. When, by reason of accident, electrical contact is established between the windings, and the frame of the machine or lamps, or between any part of the circuit and the supports on which it rests, the earth, or any pipes or other conductors in contact with the earth, then such winding or circuit is said to be grounded on such frame, pipe, or other conductor with which it has electrical connection. Grounds should be promptly removed when found. The ordinary way of locating grounds is by means of the magneto bell, one terminal of which is attached to that on which the supposed ground is, and the other terminal attached to the coil or wire which is supposed to be faulty in insulation. If the bell can be rung under these circumstances, it is fair to suppose that a ground exists, if



Bridge for Carrying Wires over Gas Pipes.

Cleats Used in Wiring.

not, the insulation is good, and the trouble must be sought for elsewhere. The wires, where a joint is needed, must be deprived of their insulation or covering and the copper scraped bright. The wires should then be twisted together and soldered, using rosin, or a weak solution of chloride of zinc, as a flux. If the latter is used it must be neutralized after completion, by wiping the joint over with a weak solution of ammonia, and then with clean water. After the joint has thus been made, it should be thoroughly covered with five thicknesses of the adherent tape provided for this purpose. It is doubtless needless to say that wherever the wires enter the binding posts of the dynamo, fuse boxes, lamps, cut outs, or other fixtures, the insulation must be removed. The wires should always be drawn taut and secured by cleats and screws indoors, and by insulators and pins outdoors, opportunity for great neatness of work is given in putting up wire.

It is always advisable to run the wires as far apart as consistent with neat work and convenience. Where wires go through walls, hard rubber tube, or some wire heavily insulated with rubber and braid, should be used.

In the case of wires entering buildings from the outside, the holes through which they pass should be bored slanting upward, and the wire bent down in a loop, so that water cannot run in on the wire. Damp places should be carefully avoided, or in case it is necessary to run wires in such places, some thoroughly waterproof insulation must be used, and the wires kept at a considerable distance from each other. It is of more importance than generally believed, to securely solder every joint in a line, and a hard solder is preferable. Make it a rule to have every joint in a circuit securely soldered, and a large amount of trouble will be avoided.

The following rules have been promulgated by the Boston Fire Underwriter's Union:

"Conducting wires must be seven feet above roofs, and placed so as to avoid ladders of the Fire Department and fire shutters. All connections must be soldered and wrapped with tape.

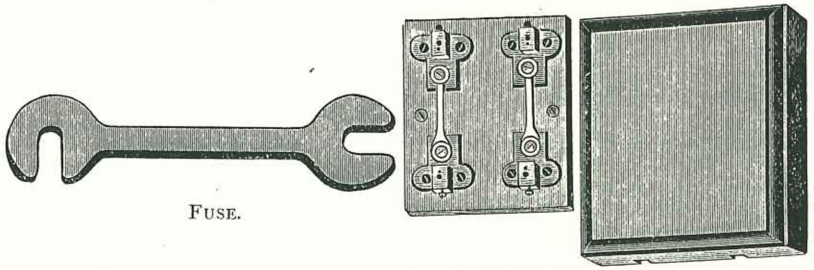
Whenever the electric light wires are in proximity to other wires, dead guard wires must be placed so as to prevent any possibility of contact with foreign wires, in case of accident to the wires or their supports. Conducting wires must be secured to insulating fastenings and covered with an insulation which is water-proof on the outside and not easily worn by abrasion. Whenever wires pass through walls, roofs, floors, or partitions, or there is liability to moisture, abrasion, or exposure to rats and mice, the insulation must be protected with rubber, stoneware, or some other satisfactory material. Wires entering buildings must be wrapped with tape, and bent in such a manner that it will prevent the water entering the building. All wires passing over or under steam, gas, or water pipes, must have a good insulation between them. Blocks of wood are the most desirable. This rule also applies to foreign wires,—they should be treated the same as pipes.

Soft rubber tube is not desirable as an insulator.

Wires should go over water pipes, where it is possible, so that the moisture will not settle on the wires.

Where incandescent wires enter buildings, they must

have double poled safety catches as near the entrance as possible."



One Form of Double Pole Fuse Box, or Safety Catch.

"The main wires must not be less than two and a half inches apart, except where they are in grooves.

The use of lead covered, or wires whose covering contains paraffine, is prohibited.

All wires that are fished over the ceiling or in the walls, must have a water-proof insulation satisfactory to this Union. This rule also applies to wires covered with moulding or concealed in any manner.

Where Underwriters' wire is used, it must be in plain sight on the walls or ceilings.

Care must be taken that the wires are not placed above each other in such a manner that water could make a cross connection.

Wires that are run in damp places must be run on glass or porcelain insulators of suitable form.

For incandescent lamps, the conducting wires leading to each building, and to each important branch circuit, must be provided with an automatic switch or cut-out, or its equivalent, capable of protecting the system from any injury due to an excessive current of electricity. These devices must be proportioned to protect the smallest wire in the loop to which they are attached.

On all loops of incandescent circuits, safety catches must be used on both sides of the loop, and switches on such loops should be double poled."

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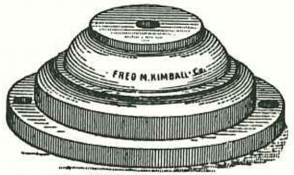
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Rosette.

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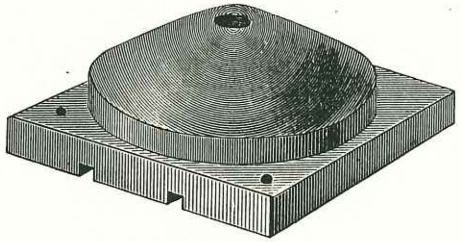
Fuse Drop Box.



Drop Box Closed.

"Ceiling blocks that are used on pendant drops, must have safety metals in them where flexible cord is used. Cord should have a knot tied in it, with the knot on the top side of the block, so that the strain will come on the knot instead of on the connection; and where it is possible, a knot should be inside of the socket the same as the block.

The small wires leading to each lamp from the main wires must be very thoroughly insulated, and, if separated or broken, no attempt made to join them while the current is in the main wires.

When wires are put on gas fixtures, the fixture must be insulated from the main pipe, and the insulator used for this purpose must be made so that the sediment in the gas will not form a connection over the insulating material.

Chandeliers or brackets attached to any ground connection, must have insulating yokes or couplings on them. Individual insulating of lamps at the sockets will not be passed except on brackets in special cases, that may be approved by the inspector."

Arc Light Wires. — "Conducting wires must be seven feet above roofs, and placed so as to avoid ladders of the Fire Department and fire shutters.

Whenever the electric light wires are in proximity to other wires, dead guard wires must be placed so as to prevent any possibility of contact with foreign wires, in case of accident to the wires or their supports. Conducting wires must be secured to insulating fastenings and covered with an insulation which is water-proof on the outside and not easily worn by abrasion. Whenever wires pass through walls, roofs, floors, or partitions, or there is liability to moisture, abrasion, or exposure to rats and mice, the insulation must be protected with rubber, stoneware, or some other satisfactory material. Wires entering buildings must be wrapped with tape, and bent in such a manner that it will prevent the water entering the building. All wires passing over or under steam, gas, or water pipes, must have a good insulation between them and the pipes. Blocks of wood are the most desirable. This rule also applies to foreign wires, — they should be treated the same as pipes.

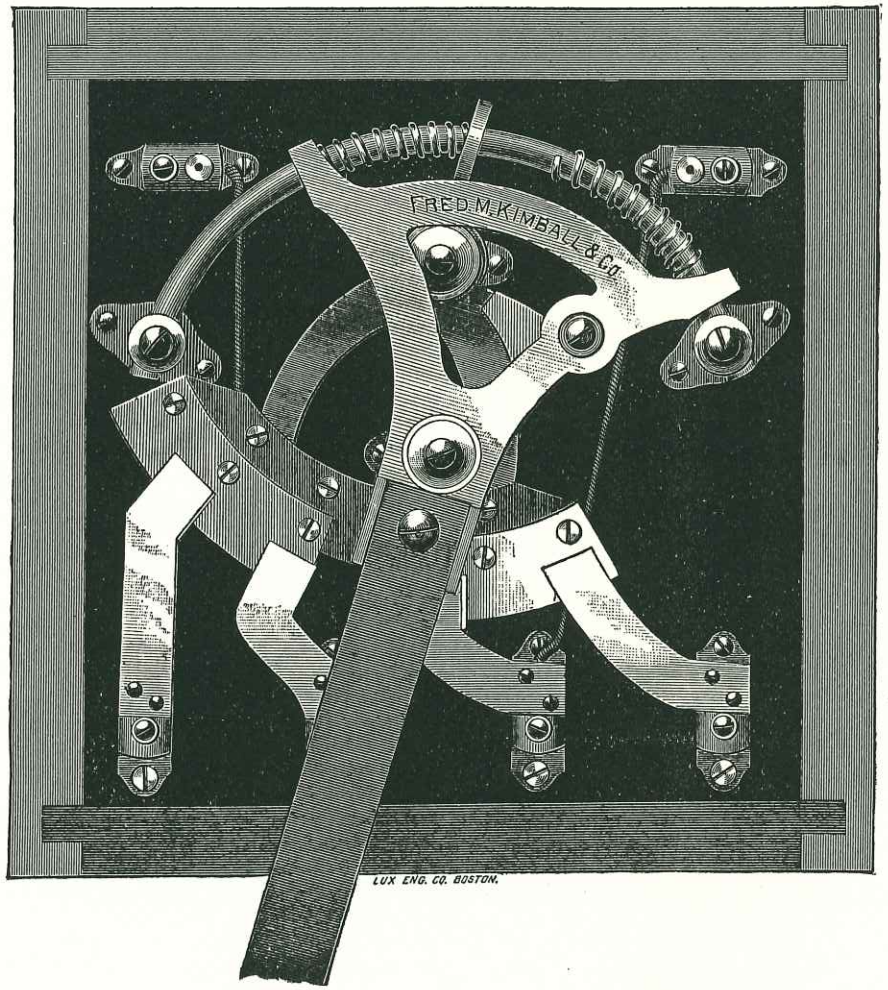
Wires should go over water pipes, where it is possible, so that the moisture will not settle on the wires.

Hard rubber hooks are not desirable as fastenings, and tacks or staples must in no case be used for fastenings or brought in contact with the wire.

In damp places, wires must be run on glass insulators, and kept entirely clear from contact with inflammable material and any substance likely to make a ground connection. The use of lead-covered wires, or wires whose covering contains paraffine, is prohibited.

The use of Underwriters' wire will not be passed where it is concealed in any manner. It must be in plain sight, on the walls or ceilings. Wire that is covered with moulding must have a water-proof insulation that is approved by this Union.

Joints in wires to be securely made and wrapped with tape; soldered joints are desirable, but not essential. Wires conducting electricity for arc lights must not approach each other nearer than one foot.



Cut out Box.

Care must be taken that the wires are not placed above each other in such a manner that water could make a cross connection.

Cut-out boxes for arc lights must have the words *On* and *Off* marked on them. They must be placed in a well-protected and accessible place, so that they can be operated by the firemen or police."

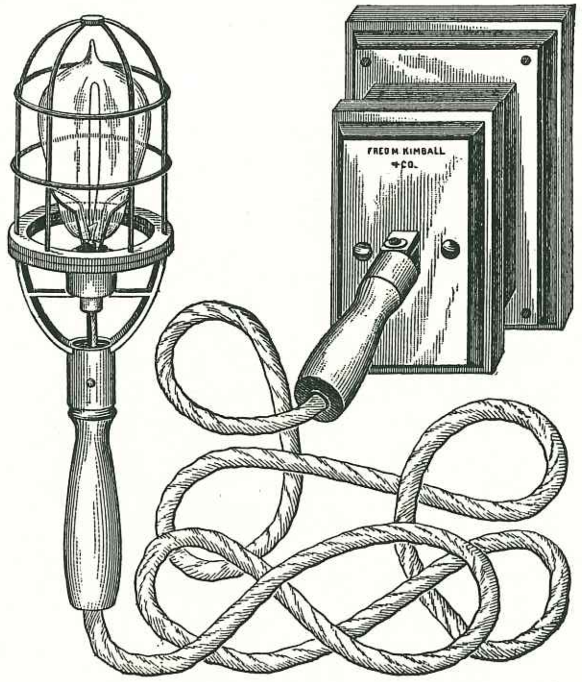
In the normal condition of the circuit, the current can only pass by way of the lamps. Through accident or carelessness, however, other ways are sometimes opened, and as the larger part of a current of electricity will always flow along the path of least resistance, if any crossing of the wires or any metallic contact takes place between the two systems, the current will go by the comparatively easy route in preference to taking the path by way of the lamps, and consequently the lamps, robbed of their energy, will cease to give light. The point where the two systems originate, positive and negative, is in the armature of the dynamo, and they must never be allowed to come into communication with each other, in any way, except through the lamps.

Incandescent lamps should be thoroughly secured in their sockets, so as to avoid possibility of shaking loose. They should not be handled with the naked hands more than is necessary, as the oil which exudes from the skin

makes the glass dull. They may be washed occasionally when they get soiled; and they may be wiped as often as is necessary with a soft cloth, to remove dust, etc. It is a matter of great importance to have the lamps firmly secured in the sockets, and the contacts firmly closed, in order that no arc may take place in the shell of the holder. Such an arc not only destroys the socket, but keeps the lamps from assuming their proper brilliancy. When one breaks, it is only necessary to remove it and replace it with a new one. In general, lamps of the same make but of varying candle power may be used in the same socket.

In putting up incandescent lamps, a small wire goes from one of the wires of the main line to one lamp, and then back to the other wire of the main line. Every lamp in order to burn must have connection with both sides of the circuit.

Lanterns and sockets are useful in mills, machine shops, etc., where it is desirable to move a light from place to place. The cords can be made of any length, and as the plugs and sockets are interchangeable, by having a sufficient number of sockets distributed through a room, it is possible to move the lantern around with the greatest facility. This is very valuable in boiler and machine shops, storage warehouses, etc.



LANTERN AND SOCKET.

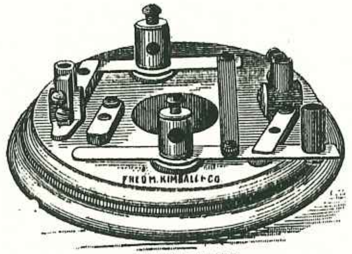
The carbon rods of arc lamps should be carefully examined for straightness and freedom from flaws and nicks. They should slide through the bushings smoothly and easily. In the case of gear fed lamps, the motion of the feeding pinion in the rack should be rather loose, but not enough to rattle. Carbon holders should be adjusted so as to be in exact line with the rods, and care should be used that the frames of the lamps are not twisted or bent so as

to throw the upper and lower carbon holders out of line. The contact springs should bear lightly but surely on the carbon rod, and this latter should be carefully cleaned every day; in the case of clutch lamps, first with fine crocus cloth, and then with light duck or canvas, and cotton waste. In cleaning a carbon rod, care must be used to draw the crocus cloth the whole length of the rod. If this is not attended to, the rod will become more worn in the centre than at the ends, and consequently the feed will not be even. It is a bad practice to use plyers to tighten carbon holder screws; use winged screws, and then sufficient grip can be taken by the fingers to lock the holder as tight as necessary. The use of plyers tends to upset the ends of the screws so that they cannot be easily drawn out to replace, and also tends to spring the carbon rod.

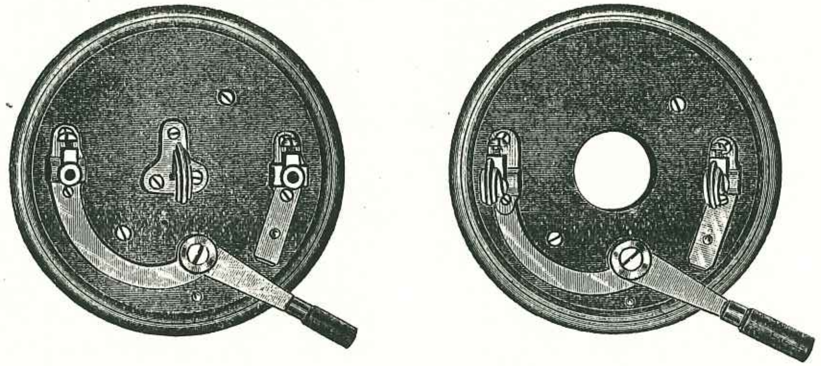
Never allow carbon dust to accumulate in the carbon guard, or on the bushings at the bottom of the lamp; many lamps have been ruined by not attending to this point. Do not allow Tom, Dick and Harry to adjust the lamps. Have one person for this work, and allow none other to open the cases. Much damage has been done by the man with the screw driver, who "thought he could fix it." Lamps should be taken to the station at certain intervals, to be repainted and looked over. Let some competent person see that all screws are set up, springs in proper adjustment, contacts perfect, etc., at stated intervals; and above all, when a lamp is working well let it alone, and do not try to make it do better.

It is the practice with some trimmers to open the case every time they trim the lamp. This is needless and should not be allowed.

We are of the opinion that it is very poor practice to rely solely on hooking the lamp into the hanger board for the contacts, cable connections should be used also. Dead



Dead Cut-out Hanger Board.



HANGER BOARDS.

cut-out hanger boards are desirable to use out-of-doors, for obvious reasons, and on the ground of safety to trimmers they should also be used indoors.

The normal speed of the dynamo will be found marked on it.

This is the proper speed for the number of lamps for which the dynamo is built. If the speed be increased the lights, if incandescent, will be brighter, although they will not last nearly as long as they ought. In other than self-regulating machines, the hand regulator may be used to compensate for changes of number of lights on the dynamo.

If the lights should at any time all go out, it will probably be from one of the following causes: (1). The set screw on the brush saddle dog slipping, and the brush springing off from the commutator. (2). The belt coming off. (3). A wire getting loose and coming out of its binding post. (4). An accidental short circuiting of the wires, and, in the case of incandescent lines, a consequent burning out of some of the fuses. The first three of these may be remedied easily by anyone. The fourth calls for a little more attention. Look over the line carefully and see that the wires are not crossed anywhere, that they do not rest on iron rods (or other metal), gas, or water or steam pipes; that they are not in a damp place; and that there is no short circuit in a lamp holder; that is, that none of the metal parts touch each other. When the trouble is found, remove it, then insert for the burned out fuses, new ones, and start up.

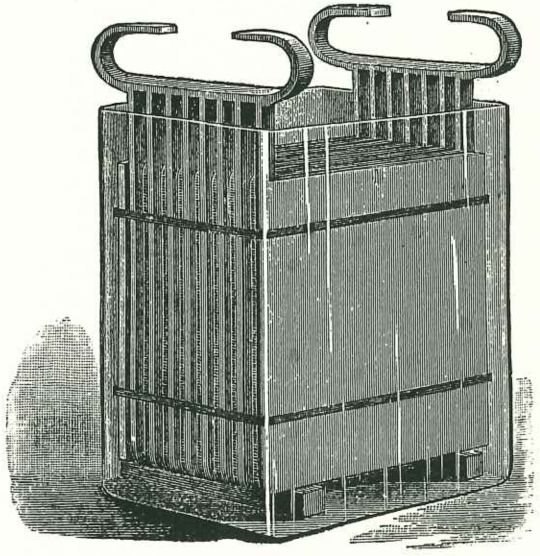
In case the dynamo will not start up, especially after polishing or turning, look carefully to see that there are no "strings" or "bridges" on its surface, and that no copper dust is bridging over the insulation of the saddle bars from the brush yoke. Be sure that all connections are tight, and all screws well set up. If there is no trouble with the commutator or connections, often just moistening the commutator with a wet finger will cause it to "pick up." The remedy for broken wires, etc., will readily suggest itself.

The dynamo should be set in a cool, dry place, where it will be free from dust and the curious fingers of experimenters. It is well to set it on a box or bench a couple of feet from the floor. All the parts are usually made to standard gauges and can readily be replaced from stock.

Where wires cross each other they should be bent up so as not to touch each other. The same remark applies to crossing pipes, etc.

Reference to the Diagram in the back of this book will show very plainly how incandescent wires are to be run, and how the various pieces of apparatus are to be connected.

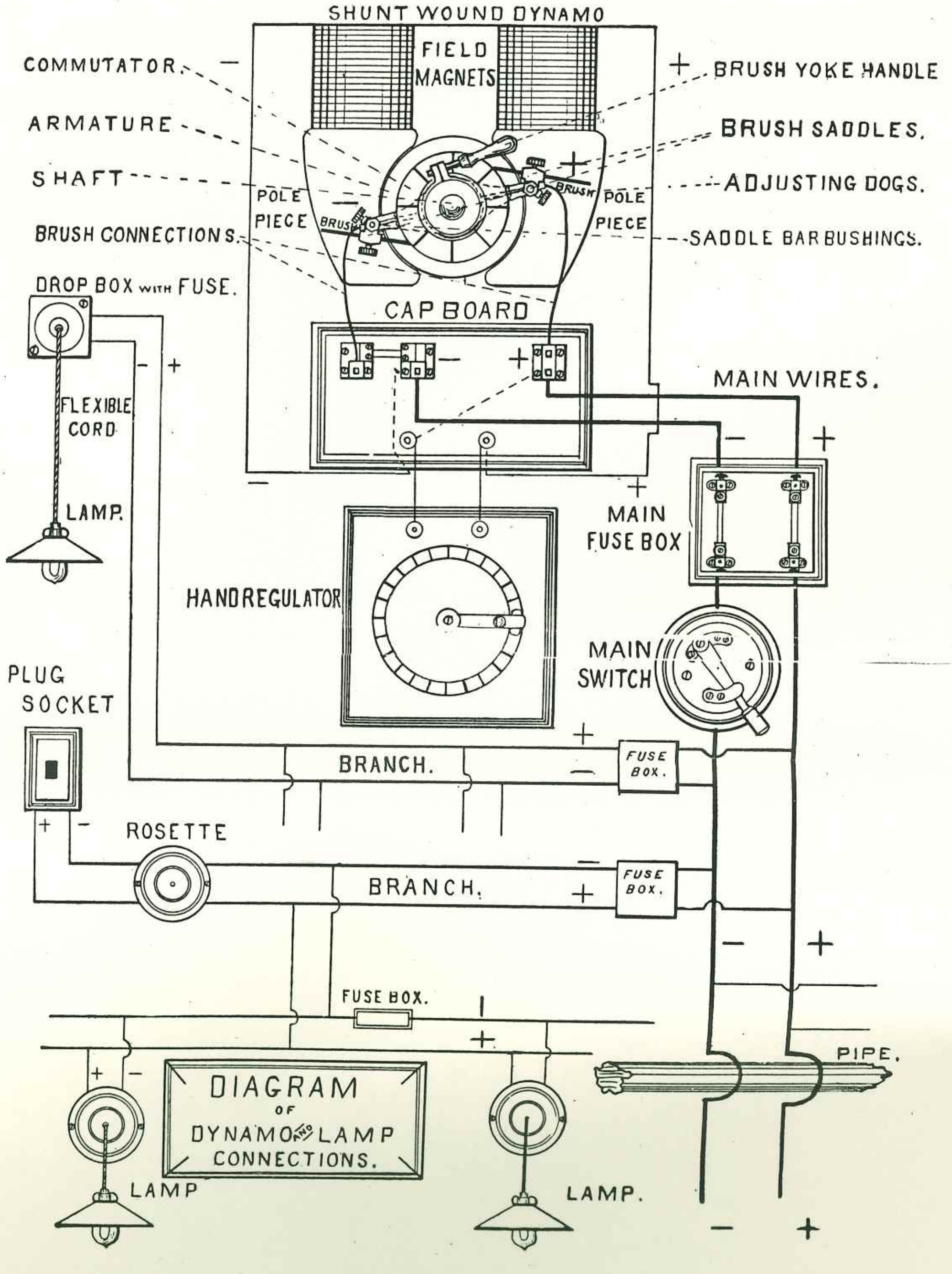
STORAGE BATTERIES.



A Storage Battery, or Electrical Accumulator, is a piece of apparatus, by means of which energy due to electrical action, may be stored up or accumulated. There is no actual storage of electrical energy, per se, but only of chemical energy, which latter is produced at the expense of the former. A cell of storage battery consists essentially of a containing vessel of glass, pottery, or rubber, in which are placed several sheets of prepared lead, side by side, and at a small distance from each other. Beginning at one end of the collection of plates, all the even numbers are joined together by a strip of lead, as also are the odd. But the system of even numbered plates is carefully arranged, so as not to touch the system of odd numbered plates in any part. After these bundles of plates are placed in the containing vessel, it is filled nearly full of acidulated water. The lead strips which connect each system of plates serve as terminals.

When the terminals of such a cell are connected with any suitable source of electricity, as a dynamo, and a current has been passing through the cell some time, a distinct change in the appearance of the plates is manifested. The system of plates connected with the positive pole of the dynamo will be found to have assumed a dark brown color, while the negative system will appear light colored, comparatively. It will be observed that in connecting the plates together, they were so arranged that the positive and negative plates alternate. The plates are known to be charged, as it is termed, when the liquid in which they are immersed, fumes, or effervesces, freely. If, after this change in color takes place in the plates, the dynamo be uncoupled, and the terminals of the cell be connected with a galvanometer, or other instrument for showing the presence of electricity, it will be found that the cell is capable

of producing a vigorous current. Several cells may be coupled up in series to give large **E. M. F.,** or in parallel for large current. Batteries may be charged from any of the direct current dynamos. But shunt wound machines are most appropriate for the purpose, as there is no liability of reversal in case the belt slips off the dynamo pulley. When Series, or compound wound machines are used, automatic switches should be included in the circuit, so that the line will be instantly opened when the dynamo stops. Storage batteries when properly used are durable, and not apt to get out of order. They should, however, be carefully looked over, occasionally, and if the acid gets low, or the plates show a tendency to warp or buckle, attention should be given at once. As an adjunct to electric lighting they are of immense importance, and in the practical application of electricity, they are destined to play a very prominent part.


SHUNT WOUND DYNAMO
FIELD MAGNETS
COMMUTATOR.
ARMATURE
SHAFT
BRUSH CONNECTIONS.
BRUSH YOKE HANDLE
BRUSH SADDLES.
ADJUSTING DOGS.
SADDLE BAR BUSHINGS.
POLE PIECE
POLE PIECE
BRUSH
BRUSH
CAP BOARD
DROP BOX WITH FUSE.
FLEXIBLE CORD
LAMP.
MAIN WIRES.
MAIN FUSE BOX
HANDREGULATOR
MAIN SWITCH
PLUG SOCKET
BRANCH.
FUSE BOX.
ROSETTE
BRANCH.
FUSE BOX.
FUSE BOX.
PIPE.
LAMP
LAMP.
DIAGRAM OF DYNAMO AND LAMP CONNECTIONS.

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